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Training the elderly in pedestrian safety: Transfer effect between two virtual reality simulation devices

Pauline Maillot[a,b,*], Aurélie Dommes[b], Nguyen-Thong Dang[b], Fabrice Vienne[b]

[a] Paris Descartes University, Sorbonne Paris Cité, Laboratory TEC EA 3625, Paris, France
[b] The French Institute of Science and Technology for Transport, Development and Networks, Laboratory for Road Operations, Perception, Simulators and Simulations, Versailles, France

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ABSTRACT

Objectives: A virtual-reality training program has been developed to help older pedestrians make safer street-crossing decisions in two-way traffic situations. The aim was to develop a small-scale affordable and transportable simulation device that allowed transferring effects to a full-scale device involving actual walking.
Methods: 20 younger adults and 40 older participants first participated in a pre-test phase to assess their street crossings using both full-scale and small-scale simulation devices. Then, a trained older group (20 participants) completed two 1.5-h training sessions with the small-scale device, whereas an older control group received no training (19 participants). Thereafter, the 39 older trained and untrained participants took part in a 1.5-h post-test phase again with both devices.
Results: Pre-test phase results suggested significant differences between both devices in the group of older participants only. Unlike younger participants, older participants accepted more often to cross and had more collisions on the small-scale simulation device than on the full-scale one. Post-test phase results showed that training older participants on the small-scale device allowed a significant global decrease in the percentage of accepted crossings and collisions on both simulation devices. But specific improvements regarding the way participants took into account the speed of approaching cars and vehicles in the far lane were notable only on the full-scale simulation device.
Discussion: The findings suggest that the small-scale simulation device triggers a greater number of unsafe decisions compared to a full-scale one that allows actual crossings. But findings reveal that such a small-scale simulation device could be a good means to improve the safety of street-crossing decisions and behaviors among older pedestrians, suggesting a transfer of learning effect between the two simulation devices, from training people with a miniature device to measuring their specific progress with a full-scale one.

1. Introduction

While most of older adults rely on walking to get around in urban areas, international crash statistics show that older people make up an extremely vulnerable road-user group (ITF, 2012). In France, more than half of all pedestrians killed in road traffic accidents are over the age of 65 though they only account for 16% of the population (ONISR, 2015). To overcome this issue, current research focuses on the development of training procedures to boost performance of older pedestrians and modify their behaviors (see e.g., Dommes and Cavallo, 2012). In this way, the present work focuses on pedestrian safety and assesses the effectiveness of a specific training procedure using virtual reality simulation.

Crossing a street is a complex task that requires several actions. First, pedestrians have to select a crossing place, approach the curb, and look for oncoming vehicles and/or traffic lights. If there is no traffic light, pedestrians have to select an adequate moment to cross by judging the available gaps in the traffic flow. In France, where the present study took place, drivers are required to stop for pedestrians at zebra crossings, but also if they show a clear intention to cross where there is no designated pedestrian crossing less than 50 m away, crossing pedestrians not being systematically protected by traffic signals or stop signs. Crash statistics indicate that French pedestrians are actually more often killed when crossing a road at a distance over 50 m from a zebra (35%, ONISR, 2015), i.e. in situa-

* Corresponding author at: UFR STAPS, Université Paris Descartes, 1 rue Lacretelle, 75015 Paris Cedex, France.
E-mail address: pauline.maillot@parisdescartes.fr (P. Maillot).

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tions where no helping signals or markings are provided and where gap-acceptance processes are required.

Greater difficulty for older pedestrians to select safe gaps when crossing and to adopt sufficient safety margin is commonly reported in the literature (Holland and Hill, 2010; Lobjois and Cavallo, 2007, 2009; Oxley et al., 1997, 2005). One of the main difficulties of older pedestrians is that their decisions are affected by the speed of approaching vehicles (Lobjois and Cavallo, 2007, 2009; Oxley et al., 2005). Older pedestrians appear to base crossing decisions primarily on the distance to the approaching vehicles rather than on the time gap, unlike young pedestrians who seem to use the time gap. For any given time gap, the distance of the approaching car is necessarily greater at high speeds than at low speeds. Considering the greater distance, older people tend to consider it safer to cross when the speed of approaching vehicle is high than when it is low. In this situation, the use of a distance-based heuristic is very dangerous and often leads to unsafe crossing behaviors. Another well-established behavior of older pedestrians is their difficulty to handle challenging traffic situations such as two-way streets. However, their street-crossing safety is significantly higher in less complex situations, such as one-way streets (Oxley et al., 1997). Older pedestrians appear to be more likely to be hit by a car during the second half of the crossing, i.e., on the far side of the street (Oxley et al., 1997; Fontaine and Gourlet, 1997). This may be because they have been shown to check mainly for vehicles approaching in the near lane before crossing, and to sometimes reach the middle of the street without looking at the far-side traffic at all (Dommes et al., 2014).

Decline in perceptual, cognitive and physical abilities associated with the normal aging process has been shown to partially account for unsafe street-crossing decisions and behaviors (Dommes et al., 2015, 2013). Older pedestrians have inadequate visual cognitive strategies, mainly due to lower perceptual and cognitive abilities (Poulter and Wann, 2013; Salthouse et al., 2003). Furthermore, older people have been shown to be particularly focused on watching their steps, to avoid falling and to maintain their balance while walking (Avineri et al., 2012), thereby neglecting active visual control during the street-crossing phase (Woollacott and Tang, 1997). There is also evidence that older pedestrians often expect drivers to adapt to them (Dunbar et al., 2004). At signal-controlled intersections, older pedestrians have even been shown not to look at the traffic at all (Job et al., 1998).

One promising way to improve older people's daily life performance is to develop training procedures (Bamidis et al., 2014). Training procedures have the advantage of controlling the type and amount of experience the individual receives and make it possible to boost learning transfers to clearly identified targets. More recently, older people training studies have included new technology (i.e., serious games, exergaming, and virtual reality). The emergence of virtual training environments is encouraging for several reasons, whether challenge through novel, difficult tasks, high variability of training tasks, specific or unspecific processing demands, or feedback (Fissler et al., 2013; Maillot et al., 2012a, 2012b). New technologies enable unprecedented control of these characteristics that appear to be essential for training effectiveness because they allow greater stimulation and learning transfer. The explanatory mechanisms of the benefits of training have not been clearly identified yet. The most plausible hypothesis involves transfer effects that refer to the generalization of learning from the training task to an untrained task. A transfer effect can be observed only if the tasks performed during the training program bring on similar solicitations to those of the evaluation tasks, in terms of cognitive processes and brain areas (Dahlin et al., 2008a; Jonides, 2004; Persson and Reuter-Lorenz, 2008).

In recent years, studies on how to train people using simulators and virtual reality have emerged in the field of road safety. These tools have already proven to be powerful training devices to prevent child pedestrian injuries (Thomson et al., 2005; Schwebel et al., 2008; McComas et al., 2002) and to teach basic driving skills (Boot et al., 2014; Kappé and Emmerik, 2005). However, training studies using virtual reality for older pedestrians are rare and inconclusive regarding street-crossing safety particularly. To our knowledge, only the studies of Dommes et al. (Dommes and Cavallo, 2012; Dommes et al., 2012) were aimed to rehabilitate the behavioral component of the street-crossing task by providing simulator-based training. The results clearly indicate the decision-making criteria gradually shifted towards more safety for all participants. However, the ability to take the speed of the oncoming car into account was not improved: after training, participants still made more unsafe decisions when the car was approaching at high speed and missed more crossing opportunities at low speed. This finding may reflect age-related perceptual and cognitive difficulties that cannot be remedied by such a training method. Moreover, the complexity of the virtual traffic environment was limited, which will have to be addressed in future training studies as older pedestrians are known to be more vulnerable on two-way streets than in one-way traffic situations. Finally, the full-scale simulation device used in Dommes et al. (2012) studies was expensive and difficult to implement by local authorities. But as this kind of devices enables actual walking, behaviors are very similar to those that can be observed in real environments (Schwebel et al., 2008). An interesting perspective could therefore be to miniaturize such a device to repeat training procedures with a large number of people and successfully implement such a prevention tool in local communities. This question has already been asked for children (Schwebel and McClure, 2010, 2014) and results have shown that small devices without active walking do highlight benefits and transferable effects to reality.

Very recently, some rare studies have also addressed the question of training older pedestrians by using video clips of real traffic situations. Rosenbloom et al. (2015) have developed an interactive computerized program to train pedestrians to successfully detect on-road hazards. But this innovative procedure failed to improve elderly participants' hazard detection significantly, suggesting that they may have already established a strategy, or that they may be less flexible in strategy creation. Above all, this program tackled hazard perception performance, rather than actual road crossing performance and the abilities of pedestrians to accurately judge a safe gap. In this line, a quick, easy-to-use training method that could be implemented in community settings has recently been tested to improve older people's crossing gap judgments. Hunt, Harper, and Lie's training program (Hunt et al., 2011) specifically aimed to teach people how to judge vehicle speed more accurately and determine whether better speed estimation made participants use speed more effectively in their gap-acceptance decisions. Three techniques were tested. The most promising one required participants to judge whether the oncoming car was travelling at an atypical or normal speed. They were given no feedback on response accuracy. A second task had them estimate car speed. The training materials included videos of traffic in real conditions. The results were encouraging. However, the task did not include actual crossing, and the extent to which speed influenced gap-acceptance decisions was not examined. Furthermore, no control group was involved. Future studies should address these questions before deciding if this method can improve older people's street-crossing decisions and behaviors. Such a method could actually also be promoted by using virtual reality. Thus, more trials could be proposed, more conditions could be tested and all pedestrians could receive immediate individual feedback on how safe their decisions and behaviors have been.

As a going concern to these rare studies, the objective of the present experiment was to develop a virtual reality training pro-